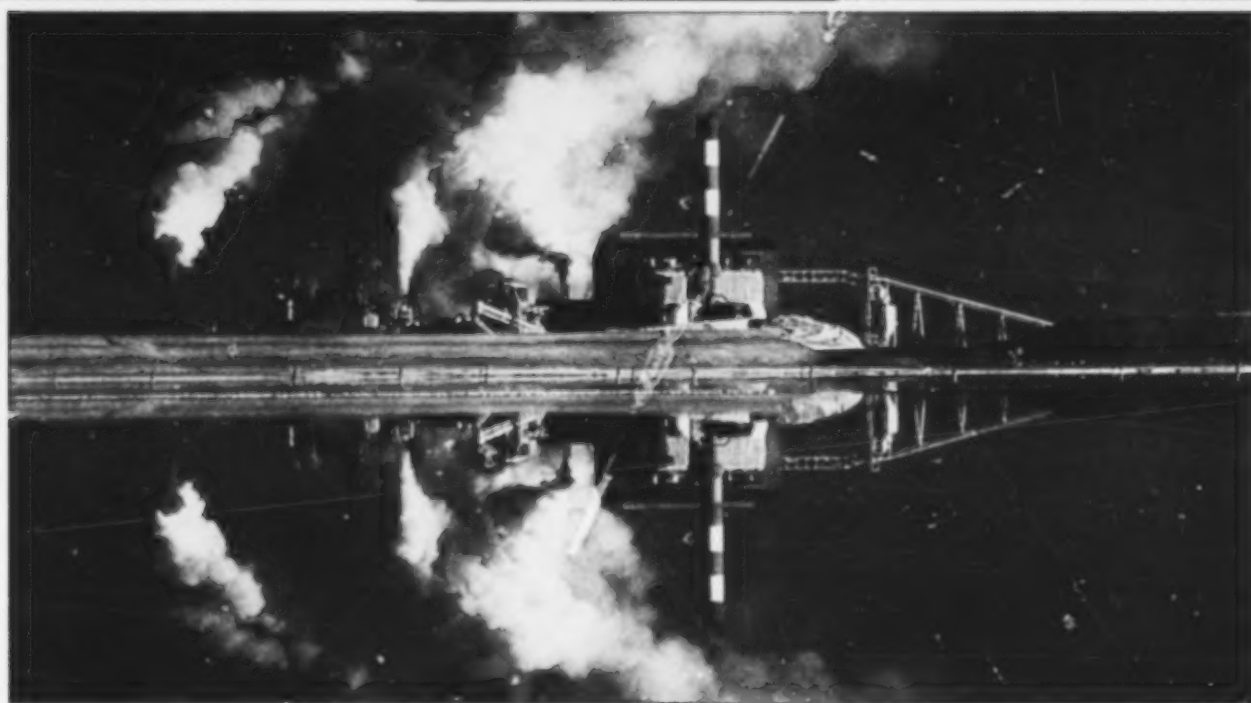


SO 116/5/990

ANNUAL REPORT



SODA ASH

By Dennis S. Kostick

1990

U.S. DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

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SODA ASH



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Director

September 1991

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COVER PHOTO:
FMC Wyoming Corp.'s Green River, WY, soda ash facility and its reflection as seen from one of its tailing ponds highlights this year's cover. FMC is the largest, oldest, and the last exclusively U.S.-owned operation in Wyoming. Although it began mining and marketing trona in late 1948 and refined soda ash in 1953, the first production from Federal leases occurred in May 1950. In 1990, on FMC's 40th anniversary of trona production from Federal land, it has become the second largest underground mine in the Western Hemisphere, with about 2,000 miles of underground tunnels. For comparison, its mine has more streets than a city with a population of 700,000. (Photo is courtesy of FMC Wyoming Corp.)

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SODA ASH

By Dennis S. Kostick

Mr. Kostick, a physical scientist with 12 years of U.S. Bureau of Mines experience, has been the commodity specialist for soda ash since 1979. Domestic survey data were prepared by Carleen Militello, mineral data assistant; and international data tables were prepared by William Zajac, Chief, Section of International Data.

Beginning with this report, all data will be reported in metric units to comply with Public Law 100-418 of August 23, 1988. This Federal law required all Federal agencies to use the metric system of measurement by the end of fiscal year 1992. Although the use of the metric measurement standards was authorized by law since 1866 (Act of July 28, 1866; 14 Stat. 339) and the United States was an original signatory party to the 1875 Treaty of the Meter (20 Stat. 709), the United States has been the only industrially developed nation that has not universally converted to the metric system from the English system of measurements. While foreign trade of soda ash increases and foreign participation in U.S. joint ventures continues, communicating information with

an international standard of measurement becomes more important.

DOMESTIC DATA COVERAGE

Domestic production data for soda ash are developed by the U.S. Bureau of Mines from monthly, quarterly, and annual voluntary surveys of U.S. operations. Of the six soda ash operations to which a survey request was sent, all responded, representing 100% of the total production data shown in this report.

Soda ash consumption by end use was collected quarterly from the industry. Trade statistics are obtained from the U.S. Department of Commerce, Bureau

of the Census. The export data collected by the Census Bureau may not correspond to the export data provided by the soda ash producers in the quarterly survey of soda ash sales. This discrepancy between the export data is because Census data reports the transaction on the date the cargo physically departed from the U.S. port whereas soda ash producers consider a shipment as exported when it leaves the plant. Overland transit time between the plant and port and any carryover export inventory are not taken into consideration.

Soda ash, also known chemically as sodium carbonate, is the 11th largest inorganic chemical in terms of production of all domestic inorganic and organic chemicals, excluding petrochemical feedstocks. Although soda ash is not a common

TABLE 1
SALIENT SODA ASH STATISTICS
(Thousand metric tons and thousand dollars)

	1986	1987	1988	1989	1990
United States:					
Production ¹	7,655	8,066	8,738	8,995	9,156
Value ¹	\$553,517	\$593,685	\$644,973	\$764,146	\$836,188
Production, Wyoming trona	12,008	12,582	13,713	14,774	14,665
Exports ²	1,859	2,018	2,238	2,648	2,392
Value ²	\$241,238	\$253,200	\$286,945	\$365,469	\$346,693
Imports for consumption	96	136	121	129	146
Value	\$15,023	\$18,334	\$15,999	\$17,396	\$20,495
Stocks, Dec. 31: Producers'	267	235	261	221	287
Consumption:					
Apparent	5,980	6,217	6,595	6,516	6,484
Reported	NA	6,100	6,494	6,469	6,527
World: Production	¹ 29,360	¹ 30,203	¹ 31,269	¹ 31,939	¹ 32,429

¹Estimated. ²Revised. NA Not available.

¹Includes natural and synthetic. Natural only, and soda liquors and mine water converted to soda ash equivalent in 1987 and thereafter, 63,469 tons in 1987, 73,365 tons in 1988, 95,027 tons in 1989, and 111,894 tons in 1990.

²Export data for 1986-88 were adjusted by the U.S. Bureau of Mines to reconcile data discrepancies among the Bureau of the Census, the American Natural Soda Ash Corp., and Statistics Canada.

household term, it is used in many consumer products found in virtually every home—glass, soap and detergents, paper, textiles, and food. The United States is the world's largest soda ash-producing nation, with the world's largest natural deposit of trona, the ore from which soda ash is refined. Because the majority of world output is made synthetically, which usually is more expensive to manufacture, U.S. natural soda ash is extremely competitive in world markets.

BACKGROUND

In 1990, soda ash represented about 2.2% of the total \$38 billion nonfuel mineral industry that was surveyed by the U.S. Bureau of Mines. The average U.S. citizen consumes about 18,140 kilograms (40,000 pounds) of new minerals in the form of consumer goods each year. Based on the 1990 U.S. population of almost 250 million, the 1990 per capita consumption of soda ash was 26 kg (58 lbs), compared with copper, 8 kg (18 lbs); aluminum, 17 kg (38 lbs); salt, 156 kg (345 lbs); cement, 328 kg (724 lbs); and iron and steel, 348 kg (767 lbs). If an infant were born in 1988, he or she would require 1,940 kg (4,344 lbs) of soda ash in his or her lifetime, based on an average life expectancy rate of 74.9 years.

Natural soda ash was probably first obtained as evaporite incrustations along the edges of alkaline lakes in Lower Egypt. It was used about 3,500 B.C. to make ornamental glassware, as evidenced by many of the early Egyptian glass artifacts. The Egyptians also mixed lime and soda ash to make caustic soda. The caustic soda was combined with silicate minerals obtained from the Sinai Desert. This made a soluble silica, which was added to aluminum-rich Nile River silt, producing a silica-aluminate cement mortar with superior bonding properties. In the Old Testament, it was referred to as neter but has also been known as natrium, kali, trona, and natron. Until the 18th century, soda ash was obtained mainly by burning seaweeds and marine plants, leaching the soluble material from the ashes, and evaporating the solutions to dryness. About 12 metric tons (13 short tons) of ash yielded 1 metric ton of sodium carbonate and 14 kilograms (30 pounds) of iodine as a byproduct. The

final material was very impure but could be used in the manufacture of glass and soap and detergents. Pliny, a Roman historian, listed soda ash in the manufacture of glass, as a medicine for colic pains and skin eruptions, and for making bread in the first century A.D.

In 1791, Nicolas Leblanc, a French chemist, developed a process for making soda ash from "salt cake" (from salt and sulfuric acid), coal, and limestone. The French Revolution interfered with its development, and Leblanc's patent and factory were confiscated, with him receiving only token compensation. Napoleon returned his factory to him, but Leblanc was not able to raise enough capital to reopen it, and he committed suicide in 1806. More than 30 years passed before the process first became successful in Liverpool, England. The process was not used successfully in the United States except during a short period from July 1884 to January 1885 at Laramie, WY.

Ernest and Alfred Solvay developed an improved method for making soda ash from salt, coke, and limestone, with ammonia as a catalyst, in the early 1860's. That process was first used in the United States in 1884 at Syracuse, NY, in a plant that continued to produce soda ash until 1986. It was the first of about 17 synthetic Solvay plants that was in operation by 1939 in the United States and, ironically, the last one to close. The Solvay process gained in popularity over the years and is now the basic method used throughout the world for making synthetic soda ash.

The site of the first commercial production of natural soda ash in the United States was from two deposits known as the Soda Lakes near the present town of Fallon, NV. Asa L. Kenyon acquired title to Little Soda Lake in 1855 and sold it to Higgins and Duffy in 1868, when the first 270 metric tons (300 short tons) of natural soda ash was produced. Production of adjacent Big Soda Lake began in 1875 and reached its peak in 1887. The brines became diluted as the lake levels rose in 1907 because regional dam construction affected the local water table.

Searles Lake in California was originally mined for borax as early as 1874. Soda ash production began in 1926 by the West End Chemical Co. American Potash Corp., formerly the American Trona Corp., was the second company to produce soda ash in 1931.

Definitions, Grades, and Specifications

The following terms are used in the soda ash industry:

Ammonia-Soda Process.—Also known as the Solvay process and lime-soda process.

Dense Soda Ash.—Has a bulk density of 0.96 to 1.06 grams per cubic centimeter (60 to 66 pounds per cubic foot). It is produced by hydrating light soda ash followed by dehydration through calcination to produce denser crystals. In eastern Europe, dense ash is made by compressing light ash between rollers to increase the density followed by screening.

Light Soda Ash.—Has a bulk density of 0.51 to 0.62 gram per cubic centimeter (32 to 39 pounds per cubic foot). It is produced by calcining the sodium sesquicarbonate precipitate recovered from the carbonation towers or vacuum crystallizers.

Natural Soda Ash.—Soda ash produced from trona ore, sodium carbonate-bearing brines, or surface mineralization.

Soda Ash.—Synonymous with sodium carbonate. It is a general term that can apply to soda ash produced from natural sources or from various chemical processes.

Sodium Sesquicarbonate.—Can refer to the name for the chemical composition of trona or the chemical process that produces a light- to intermediate-grade of soda ash having an average bulk density of 0.8 gram per cubic centimeter (50 pounds per cubic foot).

Synthetic Soda Ash.—Term for soda ash produced from one of several chemical processes, such as the Solvay process.

Trona.—The principal ore from which soda ash is made. It is composed of sodium carbonate, sodium bicarbonate, and water. The monoclinic crystals are prismatic to tabular with colors ranging from translucent (spar variety) to shades of brown, which vary depending on the amounts of contained organic matter. Trona has a specific gravity of 2.17 with a hardness of 2.5 to 3 on the Mohs' scale. About 1.8 tons of trona is required to produce 1 ton of soda ash.

The terms "soda ash" and "sodium carbonate" are used interchangeably. The material manufactured from Wyoming

trona normally contains more than 99.8% sodium carbonate, and the sodium chloride content ranges between 0.01% to 0.02%. The amount of iron is less than 10 parts per million. Searles Lake brines are processed to yield a product of similar high quality with salt and sodium sulfate as the principal trace impurities. The average material produced by a Solvay soda ash plant is about equal to the natural product in sodium carbonate content, but often contains a larger quantity of salt. Dense soda ash, because of its greater bulk density, may command a higher price than the light variety and is preferred for glass manufacture because the light soda ash leads to frothing in the glass melt. Light soda ash is preferred by many chemical and detergent industries because it dissolves more readily. Sodium sesquicarbonate has an intermediate bulk density and is used in some detergent and bath salts.

Typical official specifications for soda ash include American National Standard K60, 11-1956 (R1969) "Standard Specifications for Soda Ash," which appears as the American Society for Testing and Materials (ASTM) Designation D458-74 (Reapproved 1979); and British Standard (BS) 3674: 1963 "Specification for Sodium Carbonate (Technical Grades)." The British Standard specifies, among other requirements, not less than 57.25% Na₂O and not more than 0.005% Fe₂O₃; the ASTM, a minimum of 99.16%

Na₂CO₃. Both standards specify methods of testing.

Industry Structure

The U.S. soda ash industry is composed of six companies, five in Wyoming and one in California. All produce natural soda ash only, either from sodium carbonate-rich brines or from underground mining of trona ore. Foreign investment in U.S. soda ash operations has risen from 10% of capacity in 1981, when Société Nationale Elf Aquitaine of France bought Texasgulf Chemical Co., to 37% in 1990. Five of the six U.S. companies have either Australian, French, Japanese, or Korean partners. FMC Wyoming Corp. remains the only U.S. producer without any foreign ownership.

Geology-Resources

The definitions of resources, reserves, and reserve base are published in U.S. Geological Survey Circular 831, "Principles of a Resource/Reserve Classification for Minerals." Briefly, "resources" describe the quantity of ore present, regardless of grade or ease of extraction. The "reserves" are the portion of the resource that are economic to mine using the current technology and value of the commodity.

There are more than 60 identified natural sodium carbonate deposits in the world, the largest of which is the trona deposit in southwest Wyoming. Although

several of these deposits have been quantified, most are economically insignificant or too remote to be commercially developed. Table 4 lists the countries with known soda ash deposits. All soda ash deposits can be classified in one of five modes of occurrences. In decreasing order of economic importance, they are: buried, surface or subsurface brines, crystalline shoreline or bottom crusts, shallow lake bottom crystals, and surface efflorescences.

The trona found in the Green River Formation in southwest Wyoming is an excellent example of a buried trona deposit. The Wilkins Peak Member contains 42 beds of trona, 25 of which have a thickness of 0.91 meters (3 feet) or more. Eleven of these exceed 1.83 meters (6 feet) in thickness covering an area more than 3,100 square kilometers (1,200 square miles). The trona beds were deposited about 50 million years ago in the early to middle Eocene epoch in an ancient freshwater lake, named "Lake Gosiute" by Clarence King in 1878. The sodium and carbonate constituents of trona owe their respective origins to the leaching of the extensive pyroxene-andesite volcanic ash layers and the seasonal influxes of carbonate-rich sediments into the local depositional basin. In addition, subterranean thermal springs contributed a significant quantity of dissolved alkaline carbonates as well as sodium, calcium, silica, and bicarbonate ions. Trona can precipitate only in the

TABLE 2
U.S. PRODUCERS OF SODA ASH IN 1990

Company	Plant nameplate capacity (million tons)		Plant location	Source of sodium carbonate
	Metric tons	Short tons		
FMC Wyoming Corp.	2.59	2.85	Green River, WY	Underground trona.
General Chemical (Soda Ash) Partners ¹	2.09	2.30	do.	Do.
North American Chemical Co. ²	1.18	1.30	Trona, CA	Dry lake brine.
Rhone Poulenc of Wyoming ³	1.78	1.96	Green River, WY	Underground trona.
Tenneco Minerals Co. ⁴	1.13	1.25	do.	Do.
T.g. Soda Ash Inc. ⁵	1.18	1.30	Granger, WY	Do.
Total	9.95	10.96		

¹A joint venture between General Chemical Corp. (51%) and Australian Consolidated Industries International (49%).

²Acquired Nov. 30, 1990, from Kerr-McGee Chemical Corp., with Oriental Chemical Industries of Korea as partner (27%).

³Joint venture between Rhone Poulenc Basic Chemicals Co. of France (51%) and Union Pacific Resources Co. (49%).

⁴Owned by Texasgulf Inc., subsidiary of Société Nationale Elf Aquitaine of France (100%).

⁵Formed a joint venture with Asahi Glass Co. of Japan in Feb. 1990. The partnership provides Asahi with 20% of the full nameplate capacity of the operation when the 600,000 tons expansion is completed in late 1992.

TABLE 3
SODA ASH SUPPLY-DEMAND RELATIONSHIPS¹

(Thousand metric tons)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
WORLD PRODUCTION											
United States	7,507	7,513	7,093	7,681	7,721	7,721	7,655	8,066	8,738	8,995	9,156
Rest of world	20,839	20,501	19,714	20,210	21,513	20,514	21,705	22,137	22,531	22,944	23,273
Total	28,346	28,014	26,807	27,891	29,234	28,235	29,360	30,203	31,269	31,939	32,429
COMPONENTS AND DISTRIBUTION OF U.S. SUPPLY											
U.S. production capacity	8,727	9,398	10,124	10,124	10,124	10,124	9,580	9,512	9,512	9,580	9,950
Wyoming trona ore production	11,708	11,301	9,826	10,442	10,618	10,726	12,008	12,582	13,713	14,774	14,665
Domestic sources	7,507	7,513	7,093	7,681	7,721	7,721	7,655	8,066	8,738	8,995	9,156
Imports	16	11	16	18	15	51	96	136	121	129	146
Industry stocks, Jan. 1 ²	62	121	239	294	279	292	355	267	235	261	221
Total U.S. supply	7,585	7,645	7,348	7,993	8,015	8,064	8,106	8,469	9,094	9,385	9,523
Distribution of U.S. supply:											
Industry stocks, Dec. 31 ²	121	239	294	279	292	355	267	235	261	221	287
Exports	993	953	1,006	1,484	1,495	1,584	1,859	2,017	2,238	2,648	2,392
Industrial demand ³	6,472	6,453	6,048	6,230	6,228	6,125	5,980	6,217	6,595	6,516	6,844
U.S. DEMAND PATTERN⁴											
Glass (total)	3,494	3,357	3,176	3,130	3,085	3,084	3,152	3,343	3,390	3,294	3,177
Container	2,516	2,383	2,268	2,177	2,087	1,996	1,951	2,107	2,128	1,961	1,909
Flat	559	504	454	522	544	635	680	821	852	907	851
Fiber	175	236	200	209	227	249	272	249	246	241	228
Other	244	234	254	222	227	204	249	166	164	185	189
Chemicals	1,294	1,288	1,179	1,270	1,406	1,361	1,179	1,238	1,445	1,412	1,573
Soaps and detergents	453	454	454	562	544	544	590	684	718	781	835
Pulp and paper	227	191	249	181	227	318	181	63	111	114	132
Water treatment	227	227	209	209	272	272	227	72	110	92	91
Flue gas desulfurization	NA	NA	NA	NA	272	159	181	183	200	208	207
Distributors	NA	NA	NA	NA	NA	NA	NA	349	373	380	376
Other ⁵	777	936	781	878	422	387	470	168	148	188	136
Total U.S. consumption ⁶	6,472	6,453	6,048	6,230	6,228	6,125	5,980	6,100	6,495	6,469	6,527
Undistributed ⁷	—	—	—	—	—	—	—	117	100	47	317
Total U.S. primary demand ⁶	6,472	6,453	6,048	6,230	6,228	6,125	5,980	6,217	6,595	6,516	6,844
VALUES⁸											
Average annual value:											
Dollars per short ton	89.85	91.19	88.35	76.95	67.00	67.82	65.29	66.78	66.96	77.07	82.85
Dollars per metric ton	99.04	100.52	97.39	84.82	73.85	74.76	71.97	73.61	73.81	84.96	91.33

NA Not available; included in "Other."

¹Natural and synthetic except where noted.

²Natural soda ash only for 1980, and 1987 and thereafter: natural and synthetic from yearend 1981-86.

³Also known as apparent consumption (production + imports-exports + stock changes) and is equal to "Total U.S. primary demand."

⁴Estimated consumption for 1980-86 was based on industry sources; reported consumption 1987 and thereafter were from quantitative and qualitative quarterly surveys of producers' sales. Other end use categories were incorporated in the survey.

⁵Includes soda ash used in petroleum and metal refining, leather tanning, enamels, etc. Also includes data in categories indicated by "NA."

⁶Because end use data prior to 1987 were estimated, industrial demand and U.S. primary demand calculations (both based on production, trade, and inventory data) were assumed to be equal to total U.S. consumption. Beginning with 1987, reported consumption data by end use often disagreed with derived apparent consumption calculations that necessitated including an "Undistributed" category to account for the discrepancies. These discrepancies are because of the fluctuating balance of inventory in transit from plants to domestic or export destinations.

⁷Data may not add to totals because of independent rounding.

⁸Values are the combined total revenue of California and Wyoming natural, bulk, dense soda ash sold on an f.o.b. plant basis, at list prices, spot prices, discount, long-term contracts, and for export, divided by the quantity of soda ash sold. This value may or not be synonymous with the posted list prices of the commodity.

TABLE 4
WORLD NATURAL SODA ASH RESERVES AND RESERVE BASE
(Million tons)

	Reserves		Reserve base ¹	
	Short tons	Metric tons	Short tons	Metric tons
North America:				
United States:				
California:				
Owens Lake	50	45	55	50
Searles Lake	850	770	1,345	1,220
Colorado ^{2,3}	2,600	2,359	4,300	3,900
Wyoming ²	22,000	19,958	37,000	33,566
Total ⁴	25,500	23,130	42,700	38,736
Mexico	200	180	500	454
Total	25,700	23,310	43,200	39,190
Europe:				
Turkey	216	196	260	235
U.S.S.R.	7	6	NA	NA
Total ⁴	223	200	260	235
Africa:				
Botswana	400	363	NA	NA
Chad	8	7	NA	NA
Kenya ⁵	56	51	NA	NA
Tanzania	72	65	NA	NA
Uganda	18	16	NA	NA
Total ⁴	554	500	NA	NA
Asia: China:				
Inner Mongolia	110	100	110	100
Tongbai, Henan	132	120	132	120
Total	242	220	242	220
World total ⁴	26,700	24,200	43,700	39,644

NA Not available.

¹The reserve base includes demonstrated resources that are currently economic (reserves), marginally economic (marginal reserves), and some of those that are currently subeconomic (subeconomic resources).

²Represents only the quantity recoverable based on an average rate of 60% extraction efficiency from room and pillar, longwall, and shortwall methods of underground mining. This extraction rate does not apply to brines or surface evaporite lake beds. Solution mining of trona and nahcolite is estimated to have a 30% extraction efficiency rate.

³The sodium carbonate content of nahcolite reserves and reserve base are 0.8 billion short tons and 1.26 billion short tons, respectively. The sodium carbonate content of dawsonite reserves and reserve base are 1.82 billion short tons, and 3.0 billion short tons, respectively.

⁴Data may not add to totals shown because of independent rounding.

⁵Annual leaching of volcanic rocks replenishes the resources at Lake Magadi.

Note.—There are at least 62 identified natural sodium carbonate deposits in the world, some of which have been quantified. The countries and number of deposits include Australia (1), Bolivia (2), Botswana (1), Brazil (1), Canada (3), Chad (9), China (9), Egypt (1), Ethiopia (1), India (2), Kenya (3), Mexico (1), Namibia (1), Niger (1), Pakistan (1), the Republic of South Africa (1), Tanzania (5), Turkey (1), Uganda (1), the U.S.S.R. (4), the United States (20), and Venezuela (1).

presence of abundant carbon dioxide, which probably was supplied from the atmosphere and/or the biogenic decay of Eocene plant and aquatic remains. For 4 million years, Lake Gosiute went through many stages of filling and evaporation, thereby depositing more than 42 beds of trona on the lake bottom along

with repetitive beds of marlstone, limestone, oil shale, and sandstone-mudstone. The decrease of the inflow to the lake was probably in response to climatic changes that resulted in the final evaporation of the waters. The former Lake Gosiute is the present Green River Basin.

Assuming 1.8 tons of trona yields

approximately 1 ton of soda ash, about 47 billion metric tons (52 billion short tons) of identified soda ash resources could be obtained from the 56 billion metric tons (62 billion short tons) of bedded trona and the 47 billion metric tons (52 billion short tons) of interbedded or intermixed trona and halite that are in beds greater than 1.22 meters (4 feet) thick. Approximately 34 billion metric tons (37 billion short tons) of reserve base soda ash could be obtained from the 36 billion metric tons (40 billion short tons) of halite-free trona and the 25 billion metric tons (27 billion short tons) of interbedded or intermixed trona and halite in beds more than 1.83 meters (6 feet) thick. Although about 15 million metric tons (16 million short tons) of trona is presently being mined annually, with these minable reserves, Wyoming could supply all domestic requirements for more than 3,100 years at the 1990 demand level. As technology improves in the future, mining of the subeconomic grades of ore would further extend the life of the trona deposit to more than 5,100 years. With Wyoming reserves estimated at 20 billion metric tons (22 billion short tons), the United States, through this one deposit, could supply the world all the soda ash to meet the current demand levels for about 630 years.

The U.S. Government established a Known Sodium Leasing Area (KSLA) in Wyoming within the perimeter of the trona depositional basin. The trona within the KSLA is subject to Federal and State leasing regulations and private lease agreements. Although most of the leasable trona averages 93% sodium sesquicarbonate, several areas contain lower grade trona because of local depositional contamination along the lake margins, thereby reducing the reserve estimates of that particular area.

A series of Pleistocene playa lakes rich in evaporate minerals found in California compose the second largest reserves of sodium carbonate in the United States. Subsurface sodium carbonate-bearing brines and crystalline material compose the resource at Searles Lake, which is almost dry playa 15 kilometers (9 miles) long by 11 kilometers (7 miles) wide with an area of about 104 square kilometers (40 square miles). Surface sodium-bearing crystalline minerals predominate at Owens Lake, which was first mined in 1885 by the Inyo Development Co. Both deposits have combined reserves of about

817 million metric tons (900 million short tons).

Two potential sources of soda ash—nahcolite (natural sodium bicarbonate) and dawsonite (sodium-aluminum-carbonate)—are associated with oil shale in the Piceance Creek basin in northwest Colorado. Identified resources of 29 billion metric tons (32 billion short tons) of nahcolite and 17 billion metric tons (19 billion short tons) of dawsonite, equivalent to 18 billion metric tons and 6 billion metric tons (20 billion short tons and 7 billion short tons), respectively, of sodium carbonate resources, would be available as a byproduct of oil shale processing or as single mineral extraction. These deposits were formed in middle Eocene time with the nahcolite occurring as aggregates (62%), disseminated crystals (24%), and impure beds (14%).

The only other commercial natural soda ash deposit in the Western Hemisphere, excluding those in the United States, occurs at Lake Texcoco, near Mexico City, Mexico. Two caliche layers at a depth of 46 meters (150 feet) act as a filter and reservoir for the sodium carbonate-rich brine resource. With an average concentration of about 7% sodium carbonate, the resource contains about 180 million metric tons (200 million short tons) of available soda ash.

The Rift Valley of eastern Africa has several alkaline lakes resembling those of California. Only Lake Magadi in Kenya is presently in production. The soda ash reserves of these lakes are renewed annually from natural active volcanic sources. Other African countries that may become future suppliers of soda ash are Chad, Ethiopia, Niger, the Republic of South Africa, Tanzania, and Uganda. Botswana is developing its Sua Pan salt and soda ash deposit, and final completion of the project is scheduled for 1991. Elsewhere, deposits of natural soda ash occur in Bolivia, Brazil, Canada, India, Pakistan, the U.S.S.R., and Venezuela. Plans are underway to develop deposits in China at Xilin Gol and in the Wulan Buh desert area. A trona deposit in Turkey near Bey-pazari is also under consideration for development.

Technology

Soda ash from Wyoming trona is mined, crushed, dried, dissolved, filtered, recrystallized, and redried. In California, soda ash from sodium carbonate-bearing brines is solution mined, carbonated,

filtered, dried, decomposed, bleached, and recrystallized to dense soda ash.

Exploration.—Because of the scarcity of economic soda ash deposits in the world, many nations continue to search for new prospects. Smaller and less well known deposits are often reevaluated by different groups at different times and with usually the same results. As new techniques of exploring are developed and used, such as Landsat satellite remote sensing imagery and side-scanning radar, new deposits may be discovered.

In the United States, exploring for soda ash continues. An area near the junction of the Black's Fork and Green River in southwest Wyoming has potential. In Oregon, a few companies have expressed interest in evaluating the sodium carbonate deposits at Summer Lake and Abert Lake, which are near several pulp and paper manufacturers. These manufacturers have traditionally obtained their soda ash and caustic soda pulp-bleaching chemicals from Wyoming and Washington producers, respectively. As soda ash and caustic soda prices increase and overland transportation costs rise, these Oregon deposits may have commercial significance because their locations are nearer to the pulp markets.

Mining.—Commercial mining of Wyoming trona began in 1948. Between 1950 and 1990, more than 209 million metric tons (230 million short tons) of trona (equal to about 124 million metric tons or 137 million short tons of soda ash) have been mined. Only about 0.6% of the 36 million metric tons (40 million short tons) of halite-free trona reserve base has been used since mining began.

Underground mining of Wyoming trona is similar to coal mining, except that trona is a harder mineral than coal. The five present Wyoming soda ash producers use room-and-pillar, longwall, shortwall, and solution-mining techniques individually or in combination. The room-and-pillar method has an ore extraction efficiency rate of about 45% (55% of ore remains as pillars for structural integrity), the longwall and shortwall methods each have efficiency rates of about 75%, and solution mining has an efficiency rate of about 30%. These rates are important when calculating the amount of reserves that are minable. Based on the types of mining techniques, the author used a 60% average extraction efficiency rate to calculate reserves

(remaining 40% stays in place as pillars for structural integrity and unavailable for present extraction). The ore is undercut, drilled, blasted, mucked, crushed, and transported to the surface by well-established methods and various state-of-the-art mining equipment. The conventional blasting method using prilled ammonium nitrate and fuel oil (ANFO) is a standard and reliable method. Continuous mining uses vehicles equipped with a rotating cylindrical cutter. Continuous miners are used by T.g. Soda Ash Inc. in its shortwall technique. The longwall technique was used by General Chemical Corp. and is now used by FMC. Adopted from coal mining use, the longwall method uses a special track-mounted shearer that moves in front of a hydraulic-operated roof support system.

FMC has pioneered the use of solution mining to dissolve and recover deeply buried trona. Using an array of injection and recovery wells, a solvent (dilute sodium hydroxide) is introduced under pressure to dissolve the underlying trona. This technique has had moderate success since its first commercial debut in 1985. Beginning in 1990, FMC used the majority of the output from its solution mining for manufacture of caustic soda, from which some sodium cyanide was produced.

To reduce mining costs and maintain their competitiveness in the world, many Wyoming soda ash companies implemented continuous belt and mobile track conveyor systems to transport trona underground more efficiently. This new haulage system has replaced ore-carrying shuttle cars, reduced the mine work force, and increased the quantity of ore mined per shift. Companies have also been considering eliminating conventional mining but retaining other mining methods sometime in the foreseeable future to further reduce labor, safety, and other operating costs.

Subterranean brines between 15 and 107 meters (50 and 350 feet) below the surface at Searles Lake in California are extracted using an array of injection and recovery well drilled down to specific depths where mineral concentrations favor maximum extraction. The Argus plant of Kerr-McGee Chemical Corp. uses sodium carbonate-rich brines found in the Mixed Layer zone 67 meters to 95 meters (220 feet to 310 feet) below the surface. Solar concentration ponds are used to aerate and concentrate the brine to improve processing efficiency.

Processing.—Crushed trona is calcined in a rotary kiln at 163° to 204° C (325° to 400° F) to dissociate the ore by the monohydrate process, which produces only dense soda ash with carbon dioxide and water as byproducts. The calcined material is combined with water to dissolve the soda ash and to allow separating and discarding of the insoluble material such as shale and shortite by settling and/or filtration. The waste material is piped in a slurry to containment basins, also known as tailing ponds. The resulting clear liquid is concentrated as necessary by triple-effect evaporators or mechanical vapor recompression crystallizers, and the dissolved soda ash precipitates as crystals of sodium carbonate monohydrate, $\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$. The crystallization temperature is about 100° C (212° F), which is below the transition temperature of monohydrate to anhydrous soda ash. Other dissolved impurities, such as sodium chloride or sodium sulfate, remain in solution. The crystals and liquor are separated by centrifugation. The sodium carbonate monohydrate crystals are calcined a second time at 300° F to remove water of crystallization. The resultant finished product is cooled, screened, and shipped by rail or truck in bags or bulk.

An alternate method of soda ash production from trona is the sesquicarbonate process. Crushed trona is first dissolved and filtered to remove insoluble impurities. The liquor is evaporated in vacuum crystallizers, and the sodium sesquicarbonate precipitate is cooled to 38° C (100° F) and centrifuged to produce a pure product, which has uses as such. The sesquicarbonate can be further calcined at 204° C (400° F) to produce anhydrous soda ash of light to intermediate density.

The complex brines of the lower level of Searles Lake are first treated with carbon dioxide gas in carbonation towers to convert the sodium carbonate in solution to sodium bicarbonate, which will precipitate under these conditions. The sodium bicarbonate is separated from the remainder of the brine by settling and filtration and is then calcined to convert the product back to soda ash. The decarbonated brine is cooled to recover borax and Glauber's salt. A second dissolving, precipitating with carbon dioxide, filtering, and calcining the light soda ash to dense soda ash refines the product to better than 99% sodium carbonate.

At Owens Lake in California, crude soda ash has been mined and processed by Lake Minerals Corp. by simply digging perimeter channels allowing the interstitial fluids to drain. The surface was tilled to promote evaporation to reduce moisture content, followed by harvesting with front-end loaders.

At Lake Magadi, Kenya, crude trona is dredged from surface crusts, crushed, washed, and calcined to convert the sodium sesquicarbonate to soda ash. At Lake Texcoco in Mexico, underground brines are recovered and sent to a surface spiral concentrator to promote the solar concentration of the sodium carbonate in solution. On the Kola Peninsula in the U.S.S.R., soda ash is recovered from processing nepheline-bearing rocks. Nepheline, a sodium-potassium-aluminum silicate, is calcined in rotary kilns to yield alumina, potash, and soda ash. The alumina content of the rocks is about one-half of bauxite, but the mining and processing produces byproduct soda ash. The Petukhi and Tanatar (Mikhaylovskiy) natural soda ash lakes in Altay Kray of West Siberia provide some source of natural product.

Synthetic soda ash using the Solvay process uses salt and limestone as raw materials. A purified sodium chloride brine is saturated with ammonia and carbon dioxide gas to produce ammonium bicarbonate, which reacts with the salt to form sodium bicarbonate and ammonium chloride. The sodium bicarbonate is calcined at 177° to 218° C (350° to 425° F) to light soda ash, and the gases produced are recycled back to the liquid phase. The liquid containing ammonium chloride is reacted with milk of lime to recover the ammonia and to produce byproduct calcium chloride. Limestone and coke are required to make the milk of lime. Dense soda ash is produced by hydrating light ash to produce larger sodium carbonate monohydrate crystals. The crystals are dehydrated in dryers to change the bulk density. To produce 1.0 ton of synthetic soda ash requires about 2.8 tons of steam, 1.7 tons of salt, 1.4 tons of limestone, 0.6 ton of coal for the boilers, and about 0.2 ton of coal for the dryers. Disposition of effluent streams containing high concentrations of calcium chloride and sodium chloride is a major problem for all Solvay soda ash plants. The Solvay process discharges about 1.7 tons of waste products.

Other chemical processes can produce

synthetic soda ash. The Japanese ammonium chloride coproduction process, a variation of the Solvay process, converts all the sodium content of the salt into soda ash, whereas the Solvay process converts only about 70% of the sodium. The Japanese process also produces byproduct ammonium chloride that can be used as a fertilizer for growing rice in wetlands. The New Asahi process was also developed in Japan and uses less energy than the traditional Solvay process. An electrolysis-free process to produce vinyl chloride monomer with coproduct soda ash was developed in the Netherlands but has not been in commercial operation. The method yields soda ash instead of caustic soda and uses steam and carbon dioxide instead of electricity. The energy consumption is reported to be one-half that of the Solvay process.

Recycling.—There is no recycling of soda ash by producers; however, many glass container manufacturers are using cullet glass, thereby reducing soda ash consumption.

Byproducts and Coproducts

Borax, potassium chloride, sodium chloride, and sodium sulfate are produced as coproducts with soda ash by North American Chemical Co. in California. In Wyoming, only value added products, such as sodium bicarbonate, sodium hydroxide (caustic soda), sodium sesquicarbonate, and sodium tripolyphosphate, are produced from trona ore. Soda ash-bearing purge liquors and waste streams, normally considered waste byproducts, have been sold to powerplants for flue-gas desulfurization because of their sodium carbonate content.

Substitutes

Sodium hydroxide can be substituted for soda ash in some applications, but usually only at a higher cost and when available. About 1.3 tons of soda ash must be used to have the same chemical effect as 1.0 ton of caustic soda. Soda ash is usually shipped in dry, bulk form whereas caustic soda is transported as a liquid in various-sized closed containers.

An alternate source of soda ash is nahcolite, natural-occurring sodium bicarbonate found in a vast deposit in Colorado. The nahcolite could be converted to soda ash by calcination.

Economic Factors

Prices.—The list prices of natural and synthetic soda ash historically were identical until the mid-1970's, when higher energy costs and costs to implement the controls imposed by antipollution legislation caused the synthetic soda ash price to increase compared with that of the natural material. New natural soda ash producers came on-stream in 1976 and 1982 and contributed to slight changes in price-value trends. Changes in the domestic demand pattern also affected average annual values, especially after 1980, when domestic demand declined.

The list prices quoted in trade journals or by producers differ from the annual average values reported to and by the U.S. Bureau of Mines. The values are the combined total revenue of California and Wyoming natural bulk, dense soda ash sold on an f.o.b. plant basis at list prices, spot prices, discount, long-term contracts, and for export, divided by the quantity of soda ash sold. This value may or may not necessarily correspond to the posted list prices.

Tariffs.—The United States has a 1.2% ad valorem tariff on imports of soda ash from countries having most favored nation (MFN) status. There is an 8.5% ad valorem tariff on imports from non-MFN sources.

Many nations levy import tariffs or antidumping duties of varying percentages on U.S. soda ash. In Western Europe, an antidumping duty of 67.5 European Currency Units (about \$67.13 per ton) had been imposed on U.S. soda ash sold on the continent; however, the duty was rescinded in late 1990. Import tariffs in some other countries are the Republic of South Korea, 15%; Taiwan, 12.5%; Thailand, 10%; Indonesia, 5%; Japan, 3.9%; and Malaysia, 2%. Some of these duties will decline over time.

Taxes.—The total effective tax rate on the Wyoming trona industry is about 12.64% and comes from two major taxes. The trona severance tax of 5.5% is a State excise tax on minerals as they are removed from the ground and are applied as a percentage of assessed valuation. The collected taxes are disbursed to the Permanent Wyoming Mineral Trust Fund (2.0%), the General Fund (2.0%), and the Capital Facilities Revenue Account (1.5%). The property, or ad valorem, tax is about 7.14% of the assessed value of

TABLE 5
TIME-VALUE RELATIONSHIPS FOR SODA ASH

Year	Average annual value, dollars per ton			
	Natural soda ash			
	Actual value ¹		Based on constant 1990 dollars ²	
	Per short ton	Per metric ton	Per short ton	Per metric ton
1970	21.03	23.18	65.84	72.58
1971	21.21	23.38	62.82	69.25
1972	22.28	24.56	63.01	69.46
1973	25.36	27.95	67.37	74.26
1974	33.87	37.34	82.48	90.92
1975	42.20	46.52	93.58	103.15
1976	49.70	54.78	103.57	114.17
1977	54.19	59.73	105.88	116.71
1978	54.51	60.09	99.28	109.44
1979	64.55	71.15	107.99	119.04
1980	89.85	99.04	137.87	151.98
1981	91.19	100.52	127.57	140.62
1982	88.35	97.39	116.18	128.07
1983	76.95	84.82	97.39	107.35
1984	67.00	73.85	81.81	90.18
1985	67.82	74.76	80.42	88.65
1986	65.29	71.97	75.44	83.16
1987	66.78	73.61	74.80	82.45
1988	66.96	73.81	72.59	80.02
1989	77.07	84.96	80.24	88.45
1990	82.85	91.33	82.85	91.33

¹Values are the combined total revenue of California and Wyoming natural soda ash sold at list prices, spot prices, discount, long-term contracts, and for export, divided by the quantity of soda ash sold on a bulk, f.o.b. basis. The average annual value may not necessarily correspond to posted list prices for soda ash.

²From final 1990 implicit price deflators for gross national product, by the Council of Economic Advisors. Based on 1982 = 100.

trona produced from the mines. The ad valorem taxes on trona are higher than any other Wyoming minerals, including oil, gas, and coal. Other ad valorem taxes are placed on the assessed value of real property (buildings and equipment) and State sales and use taxes on equipment and facilities.

Royalties.—Soda ash mined on Federal lands is subject to the Mineral Leasing Act of 1920, which provides royalty payments to the U.S. Government. The Federal royalty is 5% of the quantity or gross value of the output of the product at the point of shipment to market. Each Federal lease also has other costs, such as bonds, acreage rental fees, sodium prospecting permit application fees, and permit bonds.

In Wyoming, the soda ash deposit

within the KSLA is under the jurisdiction of the U.S. Government (administered by the Bureau of Land Management), the State, and the Union Pacific Railroad, which was given alternate 1-square-mile sections north and south of the railway it constructed in the 1860's. Of the approximately 915,000 total acres of sodium mineral estate, the Federal ownership is 55.7%, Union Pacific, 38.1%; and the State, 6.2%. Sixteen lessees hold 53 active and inactive Federal leases, having a total of 75,783 acres. To prevent a possible land monopoly, no lessee may hold more than 15,360 acres of Federal land but may lease more private or State land. The State royalty rate is tied to the Federal rate of 5%; however, the private royalty rate varies. One-half of all Federal royalties collected by the Minerals

Management Service is disbursed back to Wyoming for various State and local programs.

In California, the Federal Government maintains 33 sodium mineral leases having 26,799 acres. The major lessee is North American Chemical, which produces soda ash, sodium sulfate, and salt on its sodium leases on Searles Lake.

Depletion Provisions.—The mineral depletion allowance granted to the mining industry through legislation passed by the U.S. Government has been an important inducement for companies willing to accept the risk and high cost of mining development. The concept of depletion allowances for minerals is similar to the depreciation of other assets. Although cost depletion and percentage depletion are two methods used to compute depletion deductions, most companies prefer to use the latter. About 100 mineral categories are entitled to percentage depletion. The rates range between 5% and 22% of the gross income from the mineral property, depending on the mineral and location (foreign or domestic), and are subject to a limitation of 50% of the net income from the property. The significance of percentage depletion is that the deduction is based on the quantity of the first marketable product (soda ash and not trona) and not necessarily on the amount invested. The mineral depletion allowance for soda ash is 14% for U.S. companies mining from domestic or foreign sources.

Operating Factors

Operating factors are different for mining companies than for manufacturing facilities engaged in producing natural soda ash and synthetic soda ash, respectively. The shift in U.S. soda ash production from synthetic to natural has been caused by higher costs attributed to the greater energy and labor requirements of the Solvay process and to environmental regulations. Within the natural soda ash industry, the operating factors vary for producing the commodity from brines and from trona ore.

Environmental Requirements.—U.S. natural soda ash facilities do not have difficult problems disposing of effluents. Residual insoluble material is piped to surface tailing ponds and allowed to settle. Some soda ash in solution that is not economically recoverable from processing

is discharged and is converted to sodium decahydrate in the ponds and precipitates on the bottom of ponds to become an additional source of soda ash if needed. For example, FMC has been dredging some of its sodium decahydrate, which has been accumulating since 1950. Some pond water is recirculated into the mines and used as drilling and cutting coolant. Because of changes in environmental legislation in Wyoming, Tenneco Minerals Co. has begun discharging its waste material into abandoned sections of its underground mine, thereby using less surface area on the surface for tailing ponds. The expense of underground discharge is partially offset with the reduction in costs of constructing and maintaining surface tailing ponds.

The alkaline surface ponds, with a pH up to 10.5, have posed some problems for migratory fowl that land on the ponds. The alkaline solutions strip the insulative natural oils from the feathers, thereby increasing the vulnerability of the birds to death from hypothermia. Also, birds have drowned because of the weight of sodium decahydrate that crystallizes on them when the temperature falls below 4°C (40°F). All trona producers have established a rehabilitation program to recover and release contaminated birds and to minimize the mortality and morbidity rate.

Land surrounding trona operations in Wyoming is relatively undeveloped, and the influx of large numbers of workers has caused great strain on the local facilities for housing, schools, shopping, and entertainment. Soda ash companies have provided financial assistance to aid local government in handling any overloads caused by the migration of their employees and families into the community. The companies have given financial aid to employees purchasing homes in the surrounding communities and other fringe benefits such as low-cost transportation to and from work.

Toxicity.—Although soda ash is not considered a highly toxic substance, contact with the eyes may be injurious, and prolonged contact with the skin may cause irritation, especially to those who have allergic reactions to alkaline materials. It has also been found to be corrosive to the stomach lining if ingested. It has an acute oral lethal dose (LD50) of 2.8 grams per kilogram (when tested on a rat) and a primary skin irritation index (PSII) of 2.54 (when tested on a rabbit).

Simultaneous exposure to soda ash and lime dusts should be minimized because in the presence of moisture, as from perspiration, the two materials combine to form caustic soda, which is very harmful. Soda ash is not flammable, and the dust is not explosive.

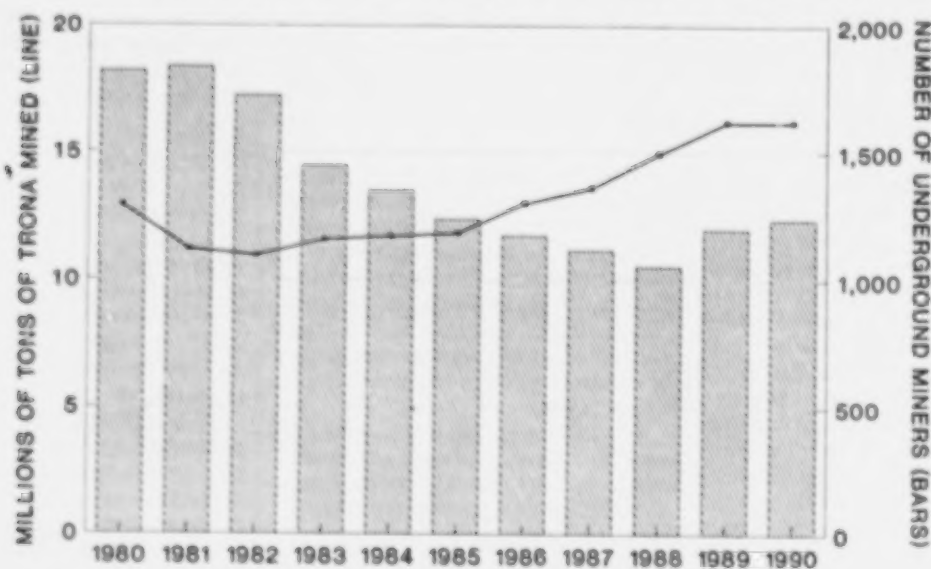
Employment.—According to the Wyoming Office of the State Inspector of Mines, the Wyoming soda ash industry in 1980 employed 3,931 people, of which 1,817 were underground workers, to produce 11.7 million metric tons (12.9 million short tons) of trona. In 1990, 3,047 people were employed, of which 1,237 underground workers produced 14.7 million metric tons (16.2 million short tons) of ore. From 1980 through 1990, the underground work force was reduced about 32%, while the quantity of trona increased 25%. This represented an 84% increase in the amount of ore mined per person per year; 6,439 metric tons in 1980 and 11,884 metric tons in 1990.

Energy Requirements.—Natural soda ash plants consume considerably less energy per unit of product produced than do synthetic soda ash facilities. As the cost of energy has increased since the 1973 energy crisis, the differential in production costs between natural and synthetic soda ash has become greater. This is one of the major reasons why U.S. natural soda ash has maintained its competitiveness in the world market.

An early U.S. Bureau of Mines energy study using 1973 data indicated that 15.8 million British thermal units (Btu) was required to produce 1 ton of synthetic soda ash, whereas the energy requirement to produce the same quantity from trona was 7.2 million Btu. The domestic soda ash industry has reduced its energy requirements significantly since 1973 by replacing gas-fired dryers with steam-tube units and installing mechanical vapor recompression units to replace triple-effect evaporators. The industry has also converted to coal exclusively or combined with other fuel sources. Plants operated by T.g. and Tenneco and the Argus plant operated by North American Chemical use coal only. As a result of these energy saving measures, the Wyoming soda ash industry lowered its energy requirement to a range of from 4.5 to 6 million Btu, depending on the individual producer. An estimated one-half of the energy consumed in natural soda ash refining using

FIGURE 1

TONS OF WYOMING TRONA MINED VERSUS NUMBER OF UNDERGROUND MINERS



Source: State Inspector of Mines of Wyoming.

triple-effect evaporators is for evaporating, one-third is for calcining, and the remainder, for drying.

These energy requirements exclude the amount of energy needed to ship soda ash to foreign markets. Although it has been estimated that it would take about 2.9 million Btu of additional energy to transport soda ash by rail and by ship to western Europe, natural soda ash production requires less energy than the Solvay process or any other synthetic technique.

Transportation.—The western geographic locations of the domestic natural soda ash industry often pose problems because of the great shipping distance to most foreign customers. Even within the United States, the majority of domestic consumption is in the Midwest and east of the Mississippi River. Overland and ocean transportation rates become important factors in the delivered price of soda ash and must be considered seriously in negotiations with foreign consumers who often have alternate supply sources. Bulk freight rates can usually be reduced by shipping in larger volumes, such as in 7,500-ton units.

The railroad is the dominant mode of transportation for the shipment of soda ash. In Wyoming, the Union Pacific Railroad provides the main service to the industry. All bulk soda ash that is railed is carried in covered hopper cars, each handling about 98 tons. Although the railroad companies make their cars available, most soda ash companies have their own sizable fleet.

Beginning in 1985, soda ash was shipped in large quantities by truck. Bonneville Transloaders Inc. trucked soda ash from Green River to the Burlington Northern Railroad's line at Shoshoni, WY. Of the approximately 8.4 million metric tons (9.2 million short tons) of soda ash produced in Wyoming, Bonneville trucks about 770,000 metric tons (850,000 short tons) out of Green River. Other trucking companies have started similar operations with the Southern Pacific (shipping more than 227,000 metric tons or 250,000 short tons per year) and Denver Rio Grande railroads to compete with Union Pacific.

The railroads have been involved in establishing soda ash bulkloading terminals at ports to handle large volumes of

material for export. Kansas City Southern Railroad's terminal at Port Arthur, TX, has a railcar unloading capacity of about 1,000 tons per hour. Material is conveyed to a shiploader spout for transfer to bulk cargo ocean vessels. Port Arthur was the third largest port of the 23 ports that shipped soda ash in 1990, most of which was shipped to South America. Longview, WA (out of the Portland, OR, customs district), has a bulkloading terminal, which transferred the most soda ash, 55%, in 1990.

ANNUAL REVIEW

Issues

The major issues in 1990 that affected the U.S. soda ash industry were the global environmental consciousness toward certain chlorine-base chemicals that altered the international chloralkali supply-demand balance; the elimination of the antidumping duties on imports of U.S. soda ash in Europe; and the movement by some domestic soda ash producers to make higher value added downstream products that use soda ash as feedstock.

The world supply and demand balance between chlorine and caustic soda historically has fluctuated. When chlorine demand was low, the availability of coproduct caustic soda was also low, which often resulted in higher prices for caustic when the market for caustic soda was strong. Some consumers temporarily switched to lower priced soda ash that was in abundant supply. This conversion usually was always a short-term cycle because the balance between the chlorine and caustic soda markets ultimately became stabilized. The present cycle of reduced supplies and higher prices, however, has lasted longer than many analysts forecasted based on previous experiences.

Major market sectors that use chlorine in products or in a process have been under pressure to reduce or eliminate chlorine use. Chlorine-base compounds such as those used in chlorofluorocarbons (CFC's) have been associated with stratospheric ozone depletion and contributing to global warming. In paper bleaching, discharges of chlorine chemicals from various pulp mills were found to contain trace amounts of carcinogenic dioxin (2,3,7,8-TCDD) and furan (2,3,7,8-TCDF).

The elimination of the antidumping duties on U.S. soda ash entering Europe raised hope for future export sales to that continent. The timing of this action was fortuitous; U.S. exports to China had drastically declined, and the U.S. soda ash industry needed replacement markets. Other important issues confronting the growth of U.S. soda ash are the political events in Eastern Europe and the reunification of the Federal Republic of Germany, both areas that have tremendous potential for increased soda ash consumption. The export opportunities are encouraging, pending a favorable resolution to the political and economic problems.

Historically, the main product produced at each soda ash plant was exclusively soda ash, which usually was sold as a raw material for other companies to make different downstream products. FMC had been producing sodium phosphates, and Rhône Poulenc had been making sodium bicarbonate, but it was apparent that many other sodium-base commodities could be made from the resource. Soda ash values between 1984 and 1988 were virtually flat because of stagnant market conditions and oversupply. In 1990, FMC, Tenneco, and

Texasgulf made plans to produce higher value added products derived from soda ash to increase corporate revenue.

Production

U.S. production of natural soda ash from California and Wyoming reached a record 9.156 million tons. About 112,000 tons of soda ash equivalent from soda liquors and mine waters was included in the total and used primarily for neutralizing powerplant process water. The liquors represent a growing market for soda ash producers and provide additional revenue.

In February, Tenneco Minerals Co. and Asahi Glass Co. of Japan formed a joint venture named Tenneco Soda Ash Joint Venture. The new \$100 million project will add 544,000 tons (600,000 short tons) of annual soda ash capacity to Tenneco's 1.13-million-ton-per-year (1.25 million short tons) facility by late 1992. Asahi will receive 20% ownership of the combined 1.67-million-ton-per-year (1.85 million short tons) operation or about 335,000 tons (370,000 short tons). This output will be exported to Japan or other areas served by Asahi.¹

On September 19, 1990, Tenneco announced plans to process an additional 1.36 million tons (1.5 million short tons) of trona into calcined trona, which can be used to produce several other sodium carbonate-base products such as soda ash, sodium sulfite, and caustic soda.² Calcining converts trona into an unrefined sodium carbonate product with some residual insoluble impurities. Because Tenneco's ore grade exceeds 93% compared with an industry average of about 89%, its calcinate contains less impurities. Calcined trona can be shipped more economically to greater distances than regular trona because the water content and other volatiles have been removed. At the customers location, the trona could be converted to caustic soda with the addition of lime and the insoluble impurities disposed to landfills.

T.g. and Atochem North America Inc., both subsidiaries of Société Nationale Elf Aquitaine of France, formed a joint venture in August to make chemical caustic soda at T.g.'s Granger, WY, facility.³ The plant will have an annual production capacity of 91,000 metric tons (100,000 short tons) with startup scheduled for early 1992. The company will use available sodium carbonate-rich mine water to produce the caustic soda. Atochem has

a chloralkali facility in Tacoma, WA, that produces electrolytic caustic soda and coproduct chlorine.

FMC commissioned its 65,000-ton-per-year caustic soda plant at Green River, WY, in March. A major portion of the caustic soda was to be used captively to make sodium cyanide for FMC's precious-metals operations in Nevada. The sodium cyanide plant, which has a capacity of 27 million kilograms (60 million pounds) per year, was operable in November. The company also brought on-stream a 60,000-ton-per-year sodium bicarbonate facility that used sodium sesquicarbonate as the raw material because it required one-third less carbon dioxide for conversion to sodium bicarbonate.⁴

The Kerr-McGee Chemical facility in California was sold November 30 for a reported \$210 million to North American Chemical, a company formed by a consortium led by D. George Harris and Associates.⁵ Oriental Chemical Industries of the Republic of South Korea, which was one of the investors, owns about 27% of the venture and has a synthetic soda ash plant at Inchon, Korea. In addition to soda ash produced at the Argus plant, North American will continue to produce various boron, potassium, and sodium products from its Trona and Westend facilities on Searles Lake.

Consumption and Uses

U.S. apparent consumption in 1990 increased 5% compared with that of the previous year, whereas reported consumption rose only 1%. The discrepancy between the two was attributed to disagreement between the sources of export data used to derive consumption statistics. The two sources were the Bureau of the Census, which reports exports upon departure from the U.S. port, and the soda ash producers, which consider a shipment as exported when their export association, the American Natural Soda Ash Corp., takes charge at the California or Wyoming plant sites. Transit times between the plant and port and carryover export inventories contribute to the discrepancy between reported and apparent consumption.

Based on reported industry sales, the manufacture of glass represented about 49% of domestic soda ash consumption, with the container sector composing 60% of this end use; flat, 27%; fiber, 7%; and specialty, 6%. The other end uses include

chemicals (primarily sodium bicarbonate, sodium chromates, sodium phosphates, and sodium silicates), 24%; soap and detergents, 13%; distributors, 6%; flue gas desulfurization, 3%; pulp and paper and miscellaneous, 2% each; and water treatment, 1%.

U.S. reported consumption of soda ash increased in the chemical, soap and detergent, and pulp and paper sectors in 1990. The rise in demand was because of greater substitution of high-priced caustic soda for less expensive soda ash by chemical consumers in the pulp and paper, chemical, and alumina industries.

Less soda ash was used in glass because of the increased use of recycled cullet. Sales to the flat glass sector declined, mainly due to the downturn in the national economy that adversely affected the building construction and automobile industries. The industrial building construction industry consumes about 57% of all flat glass made, whereas the automotive glass sector used 25%. The remainder went to specialty flat glass products.

The third largest use of soda ash is in detergents. It is used as a builder to emulsify oil stains, reduce the redeposition of dirt during washing and rinsing, provide alkalinity for cleaning, and soften laundry water. In addition, soda ash is a component of sodium tripolyphosphate (STPP), another major builder in detergent formulations, but soda ash consumption has been decreasing because phosphatic detergents contribute to the environmental problems of eutrophication. Many regions of the Nation have adopted phosphate limitations or bans. These areas represent about 33% of the U.S. population. In response to the environmental issue, detergent manufacturers began reformulating their detergents to make compact and super-concentrated products. These reformulations require sodium silicates and synthetic zeolites, which are made from soda ash. Liquid detergents, which do not contain any soda ash, compete with powdered detergents and command 40% of the household laundry detergent market, up from only 15% in 1978.

Stocks

Yearend stocks of dense soda ash in plant silos, warehouses, terminals, and on teamtracks amounted to 286,610 tons. Producers indicate that a potential supply problem could exist when inventories

TABLE 6
REPORTED CONSUMPTION OF SODA ASH IN THE UNITED STATES,
BY END USE

(Metric tons)

SIC code	End use	1987	1988	1989	1990
32	Glass				
3221	Container	2,106,662	2,128,250	1,961,039	1,908,983
3211	Flat	820,976	851,853	907,333	850,687
3296	Fiber	249,358	246,273	240,799	227,770
3229	Other	165,793	163,560	185,083	189,452
	Total	3,342,789	3,389,936	3,294,254	3,176,892
281	Chemicals	1,237,588	1,445,211	1,412,180	1,572,891
284	Soaps and detergents	684,374	717,894	780,634	834,691
26	Pulp and paper	63,001	110,996	113,962	131,973
2899	Water treatment ¹	71,568	109,865	92,268	91,057
	Flue gas desulfurization	182,899	199,630	208,296	207,067
	Distributors	349,042	373,439	380,021	375,804
	Other	169,097	147,456	187,073	136,324
	Imports ²	136,171	120,609	128,790	145,534
	Total domestic reported consumption ³	6,100,358	6,494,427	6,468,688	6,526,699
	Export ⁴	2,124,240	2,662,472	⁵ 2,644,618	2,588,478
	Total industry sales ⁶	⁷ 8,224,598	9,156,899	⁸ 9,113,306	9,115,177
	Total production	8,065,559	8,738,042	8,994,717	9,156,039

¹Includes soda ash equivalent from soda liquors, purge liquors, and mine water, sold to powerplants for water treatment. 63,469 tons in 1987, 73,365 tons in 1988, 95,027 tons in 1989, and 111,894 tons in 1990.

²Data are from the Bureau of the Census and may vary from the quantity reported by the producer/importer. Actual imports are proprietary data but have been distributed into appropriate end use categories and included in "Total domestic reported consumption."

³Reported consumption data do not agree with apparent consumption data shown in tables 1 and 3 because of dissimilar sources of export data. The data vary because of different reporting periods, overland transit times between plant and port, and carryover export inventory.

⁴As reported by producers. Includes Canada. Data may not necessarily agree with that reported by the Bureau of the Census for the same periods.

⁵Revised from monthly Mineral Industry Surveys data because of 181 metric tons (200 short tons) of misreported export data in first quarter 1989.

⁶Represents soda ash from domestic origin (production and inventory changes) and imports, and for exports.

⁷In monthly Mineral Industry Surveys reports, "Total Industry Sales" for 1987 were erroneously reported as 8,088,423 metric tons (8,915,951 short tons). The misreported figure deducted imports, which already had been included in specific end uses under "Total domestic reported consumption."

⁸An extra 23,548 metric tons (25,957 short tons) of coproducer sales is included in total, but specific end use breakout is unknown.

fall below 180,000 tons. Most consumers of soda ash do not have storage facilities to accommodate large quantities of soda ash and must rely on suppliers to provide the material on a timely basis.

Markets and Prices

There are essentially two markets for soda ash—domestic and export. In the domestic market, the large volume buyers of soda ash are primarily the major glass container manufacturers, whose purchases are seasonal (more beverage containers made in second and third quarters for summertime beverage consumption). Soda ash sales to the flat glass sector are usually dependent on the state

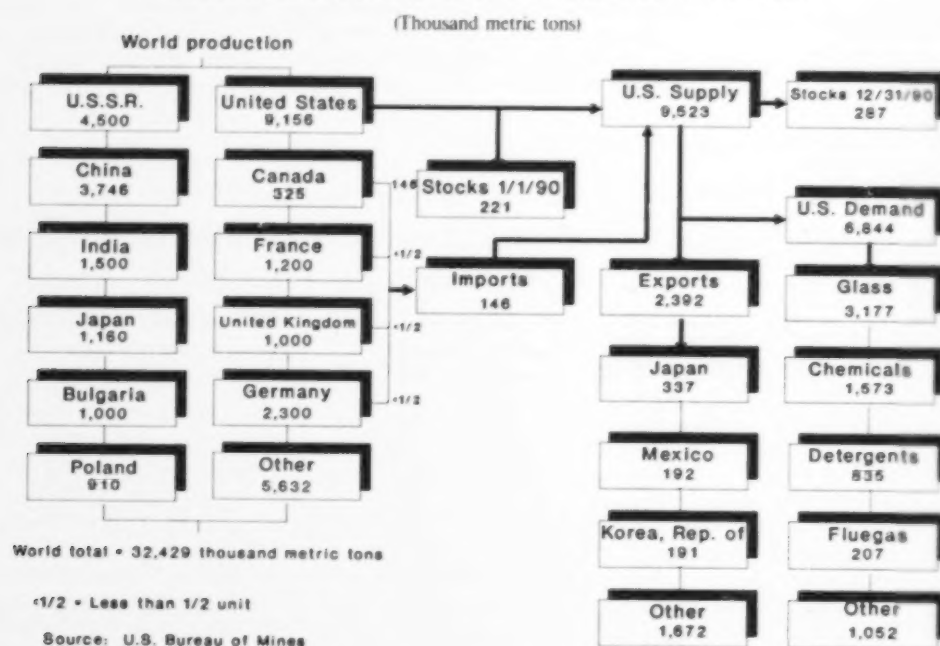
of the economy because the largest use of flat glass is in automobile manufacture and residential housing and commercial building construction. These two major industrial sectors are especially sensitive to changing economic conditions. If construction starts and automobile sales are up, soda ash sales will proportionally follow. Although there were not any increases in the list price during 1990, the soda ash industry was successful in increasing the off-list price of some contracts. The result was that the annual soda ash value increased to \$91.33 per metric ton (\$82.85 per short ton) for bulk, dense, natural soda ash, f.o.b. Green River, WY, and Searles Valley, CA.

TABLE 7
SODA ASH YEAREND PRICES

		1989	1990
Sodium carbonate (soda ash):			
Dense, 58%, Na ₂ O 100-pounds, paper bags, carlot, works, f.o.b.	per short ton	\$146.00	\$146.00
Bulk, carlot, same basis tons	do.	93.00	98.00
Light 58%, 100-pounds, paper bags, carlot, same basis	do.	150.00	150.00
Bulk, carlot, same basis tons	do.	123.00	123.00

Sources: Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. V. 237, No. 1, Jan. 1, 1990, p. 39; and v. 238, No. 27, Dec. 31, 1990, p. 31.

FIGURE 2
SODA ASH SUPPLY-DEMAND RELATIONSHIPS—1990



Foreign Trade

Exports of U.S. soda ash have increased every year since 1976, growing more than 325% between 1976 and 1989, when exports reached a record high of 2.65 million tons or about 29% of production. In 1990, however, exports decreased to 2.39 million tons because of the dropoff in export sales to China. China had been the largest consumer of U.S. exports, but its national determination to become self-sufficient in production reduced its import requirements. U.S. exports to 53 countries, on a regional basis, were as follows: Asia, 49%; South

America, 16%; North America, 14%; Africa, 7%; Europe, 6%; Oceania, 4%; the Middle East, 2%; and the Caribbean, 1%. Exports to Central America were less than 0.5%.

Section 1205 of the Omnibus Trade and Competitiveness Act of 1988 required the United States to adopt an international nomenclature and metric units for reporting trade information. On January 1, 1989, the Harmonized Commodity Description and Coding System (HS) replaced the Tariff Schedule of the United States, Annotated for import data and Schedule B for exports. The new

code numbers for soda ash are listed in the appropriate trade tables in this report.

The antidumping directorate of the European Community Commission (ECC) ruled in October that the six West European synthetic soda ash producers collectively prevented the United States from entering the European market in the early 1980's.⁶ The companies were Solvay et Cie of Belgium, Akzo N.V. of the Netherlands, Imperial Chemical Industries PLC (ICI) of England, Rhône-Poulenc S.A. of France, and Chemische Fabrik Kalk and Matthes and Weber G.m.b.H. of the Federal Republic of

TABLE 8
U.S. EXPORTS OF SODA ASH
(Thousand metric tons and thousand dollars)

Year	Disodium carbonate ¹	
	Quantity	Value ²
1986 ³	1,859	241,238
1987 ³	2,018	253,200
1988 ³	2,238	286,945
1989	2,648	365,469
1990	2,392	346,693

¹Beginning in 1989, export data were reclassified under the Harmonized Commodity Description and Coding System (HS Code No. 2836200000). Prior years were classified under Schedule B No. 4208400.

²F.a.s. value at U.S. ports.

³Adjusted by the U.S. Bureau of Mines to account for discrepancies in data.

Source: Bureau of the Census, as adjusted by the U.S. Bureau of Mines.

Germany. The combined output of these producers represented about 20% of world soda ash production. The duty of 67.5 European Currency Units (ECU's), about \$67.13 per short ton, was rescinded. ECC investigators also ruled in December that the U.S. export association would not be able to represent the U.S. producers in Europe. European soda ash consumers would prefer to have an alternate source of soda ash, namely the United States. With two Wyoming soda ash plants coowned by French companies and others that have European subsidiaries, the U.S. soda ash industry is hopeful that the investigation will result in reduced or eliminated duties, which could increase U.S. export sales to Europe.

The commission also fined Solvay and ICI a total of \$64 million (ECU 47 million) for illegal pricing arrangements and

market sharing in the early 1980's. These were the largest fines ever imposed on individual companies found violating ECC competition laws.⁷

World Review

Industry Structure.—The developed nations are generally the largest consumers of soda ash. Although the production and consumption quantities vary among the countries, the end-use patterns are basically the same (e.g., glass, chemicals, and detergents are the major sectors). Although the United States is the largest soda ash-producing country in the world, foreign ownership in the U.S. soda ash industry is presently 30% of name-plate capacity.

Eleven countries have the capability to produce more than 1 million tons annually. The major ones include, in

TABLE 9
REGIONAL DISTRIBUTION OF U.S. SODA ASH EXPORTS, BY CUSTOMS DISTRICTS, IN 1990
(Metric tons)

Customs districts	North America	Central America	South America	Caribbean	Europe	Middle East	Africa	Asia	Oceania	Total	Percent of total
Atlantic:											
Baltimore, MD	—	—	—	—	47	—	—	—	—	47	—
Miami, FL	—	17	—	335	—	—	—	—	—	352	—
New York, NY	75	—	77	—	20	—	—	1	—	173	—
Philadelphia, PA	—	—	4	—	—	—	—	—	—	4	—
Tampa, FL	—	—	—	8	—	—	—	—	—	8	—
Gulf:											
Galveston, TX	—	102	9	—	20,028	—	2	197	—	20,338	1
New Orleans, LA	—	78	8	—	—	—	—	9	—	95	—
Port Arthur, TX	1,000	2,000	222,187	14,044	62,607	9,757	38,125	—	—	349,720	15
Pacific:											
Anchorage, AK	4,899	—	—	—	—	—	—	—	—	4,899	—
Los Angeles, CA	—	8,479	74,087	—	21,390	43,248	66,819	139,949	—	353,972	15
San Diego, CA	3,659	—	—	—	—	—	—	—	—	3,659	—
Seattle, WA	2,133	—	—	—	—	—	—	—	—	2,133	—
Portland, OR	—	—	76,228	—	50,947	—	70,083	1,029,401	97,133	1,323,792	55
North Central:											
Cleveland, OH	3	—	—	—	—	—	—	—	—	3	—
Detroit, MI	86,346	—	—	—	87	—	—	—	—	86,433	4
Duluth, MN	20	—	—	—	—	—	—	—	—	20	—
Great Falls, MT	42,318	—	—	—	—	—	—	—	—	42,318	2
Pembina, ND	7,286	—	—	—	—	—	—	—	—	7,286	—
Northeast:											
Buffalo, NY	805	—	—	—	37	—	—	—	—	842	—

See footnote at end of table.

TABLE 9—Continued

REGIONAL DISTRIBUTION OF U.S. SODA ASH EXPORTS, BY CUSTOMS DISTRICTS, IN 1990

(Metric tons)

Customs districts	North America	Central America	South America	Caribbean	Europe	Middle East	Africa	Asia	Oceania	Total	Percent of total
Southwest:											
El Paso, TX	35	—	—	—	—	—	—	—	—	35	—
Laredo, TX	185,472	—	—	—	—	—	—	—	—	185,472	8
Nogales, AZ	2,656	—	—	—	—	—	—	—	—	2,656	—
Other:											
San Juan, P.R.	—	—	—	68	—	—	—	—	—	68	—
Unknown:	7,671	—	—	—	—	—	—	—	—	7,671	—
Total	344,378	10,676	372,600	14,455	155,163	53,005	175,029	1,169,557	97,133	2,391,996	100
Percent of total ¹	14	—	16	1	6	2	7	49	4	100	

¹Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

TABLE 10
U.S. EXPORTS OF SODA ASH, BY COUNTRY

Country	1980 (metric tons)	Percent of total	1985 (metric tons)	Percent of total	1990 (metric tons)	Percent of total
Algeria	41	—	—	—	4,057	—
Angola	5	—	—	—	1	—
Argentina	12,638	1	41,685	3	74,259	3
Australia	10,203	1	15,000	1	72,737	3
Bahamas	6	—	113	—	5	—
Bahrain	15	—	—	—	—	—
Barbados	—	—	3	—	—	—
Belgium	60	—	—	—	—	—
Belize	36	—	—	—	8	—
Bermuda	—	—	316	—	1,075	—
Bolivia	19	—	2,059	—	554	—
Brazil	124,309	13	58,106	4	101,873	4
Cameroon	9	—	—	—	—	—
Canada	143,759	14	132,768	8	151,480	6
Chile	10,160	1	27,043	2	39,425	2
China	—	—	33,000	—	56,159	2
Colombia	9,940	1	9,977	1	21,910	1
Costa Rica	3,064	—	3	—	8,479	—
Denmark	(¹)	—	—	—	—	—
Dominican Republic	5,187	1	4,443	—	2,722	—
Ecuador	9,808	1	5,499	—	10,634	—
El Salvador	598	—	1,032	—	—	—
France	—	—	5	—	11,474	—
French Pacific Islands	2	—	—	—	—	—
Gabon	—	—	—	—	1	—
Germany, Federal Republic of	—	—	—	—	64	—

See footnotes at end of table.

TABLE 10—Continued
U.S. EXPORTS OF SODA ASH, BY COUNTRY

Country	1980 (metric tons)	Percent of total	1985 (metric tons)	Percent of total	1990 (metric tons)	Percent of total
Ghana	24	—	—	—	—	—
Guatemala	8,503	1	11,025	1	—	—
Guyana	19	—	—	—	8	—
Haiti	7	—	55	—	41	—
Honduras	55	—	82	—	7	—
Hong Kong ²	1,109	—	492,691	31	40,734	2
Hungary	—	—	—	—	9,916	—
India	11,034	1	9,394	1	—	—
Indonesia	2,033	—	53,401	3	173,920	7
Iran	—	—	—	—	43,248	2
Ireland	—	—	3	—	(¹)	—
Israel	(¹)	—	—	—	9,757	—
Jamaica	6,539	1	3,936	—	6,059	—
Japan	57,513	6	205,713	13	337,207	14
Korea, Republic of	8,064	1	14,002	1	190,521	8
Leeward and Windward Islands	42	—	41	—	—	—
Liberia	5	—	—	—	—	—
Malaysia	—	—	15,499	1	55,844	2
Mexico	177,795	18	85,532	5	191,820	8
Morocco	—	—	—	—	600	—
Netherlands	22,178	2	—	—	20,028	1
Netherlands Antilles	13	—	—	—	—	—
New Zealand	18,678	2	39,502	2	24,397	1
Nicaragua	4	—	—	—	3	—
Pakistan	20	—	—	—	—	—
Panama	3,389	—	1,611	—	2,181	—
Peru	22,429	2	16,306	1	11,181	—
Philippines	26,784	3	42,847	3	86,095	4
Qatar	5	—	3	—	—	—
St. Lucia	—	—	—	—	5	—
Saudi Arabia	98	—	1	—	—	—
Senegal	3	—	—	—	—	—
Seychelles	3	—	—	—	—	—
Singapore ²	6,869	1	3	—	12,987	1
Somalia	—	—	2	—	—	—
South Africa, Republic of	138,077	14	130,423	8	170,370	7
Sri Lanka	—	—	—	—	9	—
Sudan	1	—	5	—	—	—
Suriname	5	—	9	—	—	—
Sweden	—	—	—	—	20,521	1
Switzerland	—	—	—	—	447	—
Taiwan ²	11,629	1	13,999	1	112,449	5
Thailand	—	—	21,224	1	103,635	4
Trinidad and Tobago	6,412	1	—	—	5,624	—
Trust Territories	—	—	4	—	—	—

See footnotes at end of table.

TABLE 10—Continued
U.S. EXPORTS OF SODA ASH, BY COUNTRY

Country	1980 (metric tons)	Percent of total	1985 (metric tons)	Percent of total	1990 (metric tons)	Percent of total
Turkey	—	—	—	—	58,530	2
United Arab Emirates	37	—	—	—	—	—
United Kingdom	18,652	2	10,049	1	34,179	1
Uruguay	331	—	—	—	2,990	—
Venezuela	114,552	12	86,048	5	109,766	5
Total ³	992,770	100	1,584,462	100	2,391,996	100

¹Less than 1/2 unit.

²The majority was bagged and transhipped to China.

³Data may not add to totals shown because of independent rounding.

Sources: Bureau of the Census and Statistics Canada, as adjusted by the U.S. Bureau of Mines.

TABLE 11
U.S. IMPORTS FOR
CONSUMPTION OF SODA ASH

Year	Disodium carbonate ¹	
	Quantity (metric tons)	Value ² (thousands)
1986 ³	96,130	\$15,023
1987 ³	136,171	18,334
1988 ³	120,609	15,999
1989	128,790	17,396
1990	145,534	20,495

¹Beginning in 1989, import data were reclassified under the Harmonized Commodity Description and Coding System (HS Code No. 2836200000). Prior years were classified under the Tariff Schedule of the United States, Annotated, TSUSA No. 4208400 (calcined) and No. 4208600 (hydrated and sesquicarbonate).

²C.i.f. value at U.S. ports.

³Also contains sodium carbonate, hydrated and sesquicarbonate.

Source: Bureau of the Census.

descending order, the United States, the U.S.S.R., China, the Federal Republic of Germany, France, Bulgaria, and India. Most of these countries have large populations that require consumer products made with soda ash. The lesser developed nations tend to have greater soda ash demand and higher rates of growth as soda ash-consuming industries are developed.

Capacity.—World soda ash production capacity is about 34.8 million tons divided among 35 countries. Approximately 70% of world capacity is synthetic soda ash, 30% natural. The United States represents 28% of world capacity and 94% of the total natural capacity.

The largest soda ash company in the world, excluding State-owned facilities, is Solvay et Cie of Belgium. It operates nine plants in seven countries and has a combined annual capacity of more than 4 million tons. FMC of the United States is the second largest with 2.59 million metric tons (2.85 million short tons) of capacity.

Botswana.—Soda Ash Botswana, the venture formed by the Botswana Government and African Explosives and Chemical Industries with its partners, the Anglo American Corp. and De Beers Holdings, commenced limited brine production at yearend. A wellfield containing 40 wells covering 200 square kilometers was developed to supply the newly constructed soda ash refinery. The wells are sunk to depths of about 35 meters. Approximately 20,000 tons of refined soda ash was expected to be produced by March 1991.⁸

Jordan.—Arab Potash Co. awarded contracts to Fluor Daniel, MDPA, and Batelle Europe to do feasibility studies of expanding the Dead Sea chemical works. Arab Potash had the intention to produce chlorine, phosphoric acid, potassium sulfate, sodium tripolyphosphate, and soda ash.⁹

Saudi Arabia.—Plans were announced by International Chemical Industries and Trading Co. Ltd. to construct a 250,000-ton-per-year synthetic soda ash plant at Jubail, near the Persian Gulf coast. One-half of the plant's production was slated for domestic consumption and the remainder for export to other Middle Eastern countries. The \$240 million facility was scheduled to come on-stream

by 1994 using Akzo Salt and Basic Chemicals International BV ammonia-soda technology.¹⁰

Turkey.—Etibank, the state mining agency, received bids from seven foreign consulting and engineering companies for planning work on a \$500 million iron project. The deposit is in Bepazari near Ankara.¹¹

OUTLOOK

World soda ash production has grown about 2.5% per year since 1970. Assuming that world production is equal to world demand (worldwide inventories are insignificant compared with output levels), world production would reach 41.1 million tons by the year 2000, based on the growth rate trend between 1970 and 1990 shown in figure 3. The environmental, energy, and economic issues of the 1980's reduced the international growth rate of soda ash to about 1.2% per annum. These issues, which will continue to be of greater importance during the 1990's, affect the overall supply and demand balance of soda ash than those events of the 1970's. Using a growth rate of 1.2% per year, world soda ash production by the year 2000 could reach 36.4 million tons, which is a conservative forecast as noted in figure 4. Developed nations, where soda ash consumption is mature and growth rates are proportional to population changes, are more concerned about environmental quality, energy efficiency, recycling, and

TABLE 12
SODA ASH: WORLD PRODUCTION, BY COUNTRY¹

(Metric tons)

Country	1986	1987	1988	1989	1990 ^c
Albania ^c	32,000	31,000	30,000	30,000	30,000
Australia ^c	300,000	300,000	300,000	300,000	300,000
Austria ^c	150,000	150,000	145,000	150,000	150,000
Belgium ^c	481,656	447,972	378,960	^c 380,000	380,000
Brazil	201,000	170,000	184,416	^f 196,526	200,000
Bulgaria	1,054,214	1,070,188	^e 1,100,000	^e 1,100,000	1,000,000
Canada ^c	350,000	325,000	325,000	325,000	325,000
China	^f 2,146,000	^f 2,363,000	^f 2,609,000	^f 3,042,000	² 3,746,000
Colombia	112,920	116,864	114,087	^e 115,000	115,000
Czechoslovakia	113,000	^f 102,659	^f 112,217	^e 110,000	100,000
Denmark ³	117	^e 120	^f 134	^f 140	140
Egypt ^c	50,000	^f 45,000	² 47,711	47,000	47,000
France ^c	1,245,000	1,270,000	1,270,000	1,300,000	1,200,000
Germany, Federal Republic of:					
Western states	1,442,000	1,448,000	1,404,000	^f 1,443,000	1,450,000
Eastern states	885,000	893,000	914,000	^e 900,000	850,000
Total	2,327,000	2,341,000	2,318,000	^f 2,343,000	2,300,000
Greece ^c	^(d)	^(d)	^(d)	^(d)	—
India	873,600	969,600	^f 1,098,200	^f 1,343,500	1,500,000
Italy ^c	590,000	612,000	612,000	615,000	610,000
Japan	1,020,849	1,098,465	1,083,121	^f 1,105,308	1,160,000
Kenya ⁵	237,650	228,650	220,000	240,880	240,000
Korea, Republic of	264,213	288,500	^e 280,000	^e 280,000	280,000
Mexico ⁶	^f 405,344	^f 417,329	421,158	456,466	475,000
Netherlands ^c	380,000	380,000	^f 400,000	^f 400,000	400,000
Pakistan	130,894	^f 133,133	134,106	^e 135,000	135,000
Poland	963,000	930,000	^f 956,000	^e 910,000	910,000
Portugal ^c	155,000	160,000	155,000	150,000	150,000
Romania ^c	850,000	860,000	860,000	800,000	800,000
Spain ^c	525,000	550,000	560,000	560,000	550,000
Switzerland ^c	43,000	23,000	—	—	—
Taiwan	133,358	127,332	126,828	^f 115,572	120,000
Turkey ^c	330,000	376,000	379,000	^f 381,000	385,000
U.S.S.R. ⁷	5,032,000	5,049,000	5,097,000	^f 4,809,000	4,500,000
United Kingdom ^c	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
United States ⁸	7,655,001	^f 8,065,559	8,738,042	8,994,717	² 9,156,039
Yugoslavia	207,968	201,539	213,891	^f 204,050	165,000
Total	^f 29,359,784	^f 30,202,910	^f 31,268,871	^f 31,939,159	32,429,179

^cEstimated. ^fRevised.

¹Table includes data available through Apr. 26, 1991. Synthetic unless otherwise specified.

²Reported figure.

³Production for sale only; excludes output consumed by producers.

⁴Revised to zero.

⁵Natural only.

⁶Includes natural and synthetic. In 1988 and 1989, Mexico produced an estimated 180,000 metric tons per year of natural soda ash. The new series listed is as reported by Asociacin Nacional de la Industria Quimica, beginning with 1986.

⁷Excludes potash for 1986-87.

⁸Natural and synthetic for 1986, natural only thereafter.

FIGURE 3
U.S. AND WORLD SODA ASH PRODUCTION GROWTH RATES

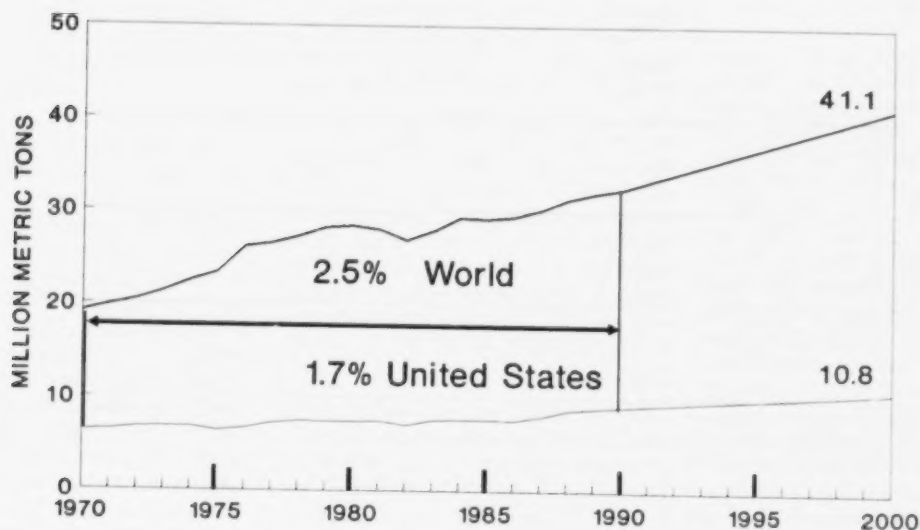
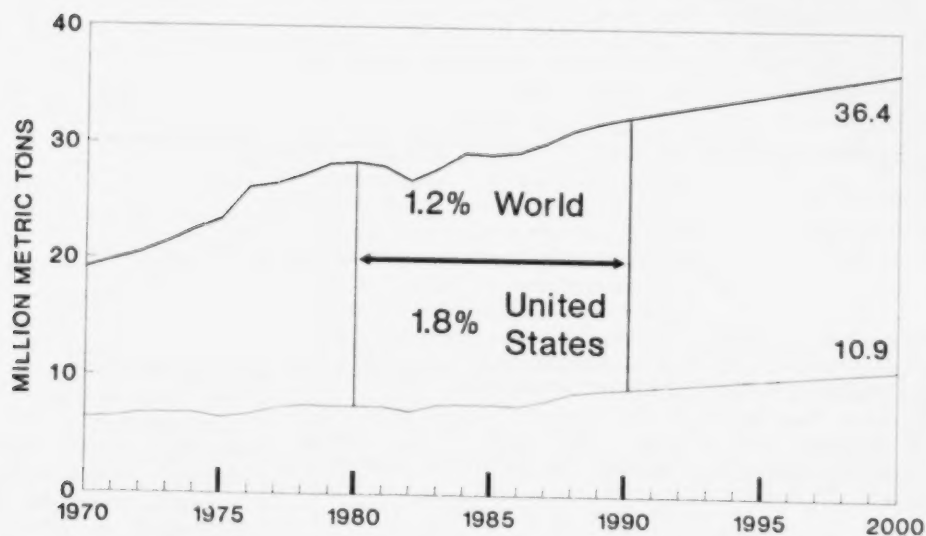


FIGURE 4
U.S. AND WORLD SODA ASH PRODUCTION GROWTH RATES



and consumer preferences—all of which have an adverse affect on soda ash usage. Developing countries still have a greater demand for soda ash but often have less hard currency to purchase all their requirements.

The U.S. annual growth rate for domestic production since 1970 has been

about 1.7% per annum. The 1973 energy crisis and subsequent higher fuel costs changed the operating factors between competing natural and synthetic soda ash industries. U.S. production was close to what was forecast for 1990 in the 1985 "Mineral Facts and Problems." The export market grew greater than anticipated,

mainly through the efforts of the industry's export association, and raised total industry sales despite periods of stagnant domestic sales.

Domestic production is forecast to grow at 1.8% per year and reach 10.9 million tons by the year 2000, as indicated in figure 4. This growth rate, based

on the trend between 1980 and 1990, is similar to the 21-year pattern from 1970 through 1990.

Exports

The outlook for soda ash is excellent. Export opportunities to the Middle East and Western and Eastern Europe are very favorable. With the removal of the ECC antidumping tariffs on U.S. soda ash, more soda ash will be exported to Western Europe in the near future. The changes in the political situation in the U.S.S.R. and Eastern Europe may also lead to more U.S. exports to meet the growing demand for consumer products in those areas. The limiting factor, however, may be the lack of available hard currency and the internal manufacturing capabilities of the industries that use soda ash.

The future of reestablishing U.S. exports to China is uncertain. China has been debottlenecking several synthetic soda ash plants and constructing new ones, but production has not kept pace with demand. China was forced to reduce its soda ash consumption by limiting imports because of economic problems. Bulgaria had supplied some of China's requirements; future shipments could be curtailed to satisfy Eastern Europe's needs, thereby reducing Bulgaria's level of exports. This could allow the United States the opportunity to continue to supply China, pending the availability of U.S. product. Despite these obstacles, total U.S. exports could grow by at least 400,000 tons in the next several years.

Glass

Although glass is the largest end use of soda ash, domestic consumption in the glass container sector is declining because of (1) the increasing use of cullet (2) the national interest in recycling, and (3) the continuing competition with polyethylene terephthalate (PET) plastic containers.

Glass container shipments were less in 1990 than in previous years. The public's perception that glass is completely recyclable compared with plastics will raise the quantity of cullet now being consumed. Aside from the problems with plastics' recyclability, the public also is concerned about the dioxin emissions from incineration of polyvinyl chloride (PVC) bottles. Flat glass consumption was also down because of adverse

economic conditions affecting housing starts and automobile sales. This situation is temporary because interest rates will decline for home mortgage loans.

Municipal landfills are a growing national problem. Glass reportedly accounts for 8.4% of disposable household waste. The U.S. Environmental Protection Agency has a goal of reducing the Nation's waste by 25% by 1992. It is probable that new taxes will be placed on items manufactured at the source of production to encourage greater use of recycled products. Rebates would be given for every ton of recycled material utilized.

Chemicals

The global chloralkali supply and demand imbalance will continue to be an important topic for the next few years. The demand for PVC products will govern chlorine supplies and the availability and price of coproduct caustic soda. Chemical caustic soda produced by the lime-soda process will satisfy part of the projected caustic soda shortages. For foreign shortages, trona deposits outside the United States will be evaluated as potential natural sources to produce chemical caustic soda.

Soap and Detergents

About 10 million tons of laundry detergents is consumed annually in the world. Most detergents are composed of many active and inert chemical ingredients. Household liquid detergents and phosphate-free detergents are considered environmentally safe products. More soda ash has been added as a phosphate-replacement builder in various detergent formulations to meet regional phosphate discharge requirements.

The environmental movement in Europe has also prompted foreign detergent manufacturers to consider changing formulations to reduce phosphate content. In the Federal Republic of Germany, consumption of phosphates in detergents dropped from 276,000 tons in 1975 to 80,000 tons in 1987. The quantity of packaging waste discarded to landfills prompted detergent manufacturers to test market compact and superconcentrated products in different regions. Whatever amount of soda ash lost due to reformulation could be partially offset from the use of soda ash in synthetic zeolites and sodium silicates in the new formulations.

Consumer preferences also may determine the preferred detergent and format (i.e., liquid versus powdered, unit dose packets versus bulk). Depending on the choice, the growth of future soda ash sales is optimistic.

Pulp and Paper

Although the U.S. pulp industry is growing at about 2.75% per year, changes are taking place to alter the pulp- and papermaking processes. Pulp mills are striving to address the environmental issues regarding dioxins and furans, improve productivity, reduce costs, and improve paper quality. One solution is alkaline paper sizing, which produces alkaline-based paper rather than acid-based. The conversion is not being implemented as fast as the environmental issue is mounting. Other alternatives include substituting certain pulping chemicals.

Dioxins, created from chlorine molecules introduced in the paper-bleaching process, have been detected in bleached paper products as reported in a study of the 104 kraft-pulp mills in the United States. To avert the public's reaction to the issue, the industry began investigating substituting chlorine-base chemicals for nonchlorine pulping and bleaching agents, such as oxygen and hydrogen peroxide. About 1.8 million tons of chlorine is used in pulp bleaching annually. Industry sources estimate a 25% to 30% reduction in chlorine consumption by 1995. If this forecast is accurate, coproduct caustic soda, which is used to delignify wood pulp, could be in short supply. This situation could result in additional quantities of soda ash being used instead of caustic soda, although it would take 1.3 tons of soda ash to have the same chemical effect of 1.0 ton of caustic soda. FMC, Tenneco, and T.g. have made announcements to produce caustic soda from their Wyoming soda ash operations. Although the majority of the output is for captive needs, the opportunity will demonstrate the economic feasibility of producing caustic soda from nonsalt feedstocks. Soda ash consumption in the pulp and paper sector could increase during the next few years depending on the strength of chlorine demand, which is influenced by the strength of PVC sales.

Flue Gas Desulfurization

The Clean Air Act, as amended by Public Law 101-549, will require the

Nation's powerplants to reduce emissions of sulfur and nitrogen compounds produced from burning fossil fuels. Although most high-sulfur coal is used in Eastern powerplants where inexpensive calcium-base compounds are located, sodium-base sulfur dioxide removal agents, such as trona and nahcolite, have opportunities for commercial development in the West.

In 1990, approximately one-quarter million tons of soda ash was used for reducing harmful stackgas emissions in the West and Midwest. Transportation costs will reduce the competitiveness of sodium minerals in the East in the future; however, the concern regarding water quality and quantity will be major issues in the Western United States in the 1990's. Several wet-scrubbing utility plants, which use tremendous amounts of water, are evaluating the economics of replacing traditional wet-scrubbing systems using lime with dry-injection technologies using calcium- and sodium-base agents. The addition of some sodium minerals removes additional sulfur and a substantial amount of the nitrogen materials. Eastern powerplants will probably use low-sulfur coal rather than use trona or nahcolite resources found in the West. When Western powerplants retrofit older facilities with dry-injection scrubbing equipment to conserve water, demand for soda ash will increase.

Soda Ash Industry

Although the outlook for the U.S. soda ash industry is very good, the structure of the industry continues to change as foreign participation increases. The United States will remain an important supply source of inexpensive natural soda ash for international consumption. However, a growing percentage will be shipped by the foreign partners of the U.S. resource—primarily Australia, France, Japan, and the Republic of Korea. More shares of the U.S. soda ash industry are available for joint venture at the present time. It is unlikely that any new grassroots operation will be constructed in the United States for the remainder of this century.

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